DISCOVERY

Evaluation of some rheological properties of *Jatropha curcas* l. Seed oil necessary in overcoming energy crisis problem

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ABSTRACT

This research was carried out to investigate the rheological properties of *Jatropha Curcas L.* seed oil. The parameters studied were the dynamic viscosity of the oil and the shear stress at different shear rate and temperatures. The dynamic viscosity was measured to be 151.8cp to 98.8cp at 6rpm, 82.0cp to 51.9cp at 12rpm, 42.2cp to 22.9cp at 30rpm and 25.3cp to 14.9cp at 60rpm all at varying temperatures of 30^{o}C to 70^{o}C using NDJ-S5 viscometer. The shear stresses obtained ranged from 91.8 N/m^2 to 59.28 (N/m^2) at varying temperatures ranging from 30^{o}C to 70^{o}C at 10^{o}C intervals, and were dependent on the shear rates. The results showed that viscosity decreased with an increase in temperature. Power law model was used to describe the viscosity to shear stress relationship and the flow behavior index (n) obtained which were closed to one indicated that *Jatropha Curcas L.* seed oil exhibited a Newtonian behavior. The results can be used to predict the design texture, storage and flow processes of *Jatropha Curcas L.* seed oil which is necessary overcoming the energy crisis issue and limiting environmental changes.

1. INTRODUCTION

The words "Jatropha" are Creek words that indicate "doctor" and "nutrition," respectively, according to Brittania and Lutaladio, (2010). Curcuas Jatropha L is also known as the purging nut, vomit nut, bubble bush, and physic nut. It has many potentials uses and can therefore generate revenue in rural areas of underdeveloped countries, according to Salawu et al., (2011) and (Isam et al., 2011). Its production per hectare exceeds that of soy beans and corn by more than four and ten times, respectively (Sepidar et al., (2009); Nobrega & Sinha, 2007). *Jatropha Curcas L* is known in Nigeria local languages as Olulu-idu for the Igbos, Lapa/zugu for the Hausa and Botuje for the Yorubas. *Jatropha Curcas L* has a very good quality feed stock for diesel production. The biodiesel produced from Jastropha oil meets the America and European diesel standard (Makkar et al., 1998). Makkar and Becker, (1997) investigated that after extraction of oil from the seed the by-product which is called seed cake has high nutrition composition such as crude protein 55-63%, 1-15% of lipid 8.1-9.1% of crude fiber. The seed cake can be utilized as a microbe's substrate to manufacture enzymes like proteases and lipases as well as has tremendous potential for biomass and

biodiesel production. It also produces more energy during fermentation than cow manure (2009).

Both the fruit shell and seed husk of the jatropha plant are suitable for direct combustion; the fruit shell can be dried, ground to a fine powder and then shaped into fuel briquettes. After burning, the left-over ash has a high potassium content that can be applied to crops Singh et al., (2008). According to research by Heller, (1996) and Nath and Dutta, (1992), the Jatropha Curcas L plant has a variety of therapeutic uses, including the ability to reduce rheumatic pain when the seed oil is administered, paralysis and the latex is used for healing wounds and curing different skin diseases such as ringworms, eczema, derma mycosis, scabies, ulcers, remove pains and stings of bees and wasps and sarcoptic manger in sheep and goats. Openshaw, (2000), Messenmaker, (2008) and Warra, (2010) demonstrate the use of Jatropha Curcas L seed oil in the manufacture of cosmetics. This oil has the potential to be produced into a viscous substance that is used in the manufacture of soap. He also looked into the possibility that the soap might have medicinal properties and be used to treat a variety of skin conditions.

Research has been done on the physical, chemical, physiological and byproducts of Jatropha Curcas L, however the rheological characteristics of the oil extraction processes from Jatropha Curcas L seed have not been discussed in technical literature. The goals of the study project are to extract oil from Jatropha Curcas L seeds using the Soxhlet process, fit the power law model using a viscometer and ascertain the oil's dynamic viscosity. Proper equipment design for handling, shipping, storage, processing, and product quality assessment is made easier with knowledge of the property and flow behavior.

2. MATERIALS AND METHODS

Sample Preparation

20g of Jatropha Curcas L seed was purchased from Ibadan, Oyo State, Nigeria. The chemical engineering laboratories (Reaction engineering and kinetic laboratory and Reservoir/production laboratory) of the college of engineering, Niger Delta University, utilised n-hexane, which was purchased from Yenagoa, Bayelsa State. The healthy and good seeds were physically separated from the damaged ones and the unhealthy ones were thrown. The 20g of good seeds that were chosen were cracked and the shells were removed. The kernels were then dried at a high temperature of 100°C to 105°C for 35 minutes to guarantee that the moisture from the seed was gone. To ensure that any free oil was captured, the dried seeds were ground using a grinder (see plate 1) and the oil was extracted using the Soxhlet process (see plate 2). Using a Golden Meter USA electronic balance, the oil was kept in the sample flask (see plate 3). According to Akbar et al., (2009) the Soxhlet extraction process is used to extract oil from raw materials. Equation 1 was used to calculate the oil yield at the conclusion of each trial as a percentage of the seed's extract.

$$\%\ \text{oil yield} = \frac{\text{weight of oil extracted (g)}}{\text{weight of seed sample used (g)}} \times 100. \qquad (1)$$

Plate 1 *Jatropha Curcas L.* Dry seed

Plate 2 Soxhlet apparatus

Plate 3 Golden meter USA electronic balance

Determination of Rheological Properties

The rheological properties of *Jatropha Curcas L.* seed oil were determined using NDJ-5S viscometer see plate. 4. The viscosity of the oil was measured with spindle number sp-4 at different shear rates of 6, 12, 30 and 60rpm and temperatures ranging from 30 to 70^{o}C at 10^{o}C intervals. The temperature of the oil was increased using Stuart water bath-RE300B see plate.5 and temperatures measured using laboratory thermometer. The shear stress was determined using the shear stress to shear rate relationship as represented in the equations 2.

$$\eta = \tau/\gamma \qquad (2)$$

Where; η= Dynamic viscosity in (cP,) τ = shear stress (N/m^2); and, γ = shear rate (1/s).

Plate 4 NDJ-S5 Viscometer

Plate 5 Stuart water bath-RE300B

Power Law

Equation 3 illustrates how the experimental results on viscosity were analyzed fitting the power law.

$$\tau = k\gamma^{n} \quad (3)$$

Where;

k = consistency coefficient

n = the flow behaviour index

τ = shear stress

γ = shear rate (1/s).

For shear thinning (pseudoplastic) fluids $n<1$

For shear thickening fluids $n> 1$.

Newtonian fluids, $n = 1$ and $k = \mu$

Microsoft Excel 2010 was used to calculate the consistency coefficient and flow behavior index.

3. RESULTS AND DISCUSSION

Oil yield

The extraction technique produced 78% oil from the 20g of the ground meal from Jatropha Curcas L. This indicates that when oil was extracted using a soxhlet method, the ground meal of Jatropha curcas L. generated 78% oil.

The Rheological Parameters

The experiment's findings demonstrated shear stress and shear rate in connection to each other, viscosity and temperature and shear stress alone as shown Figures 1and 2. Table 1 displays the experimental data for the investigated bio-viscosity oil at various temperatures and share rates.

Table 1 The experimental data for the viscosity of *Jatropha Curcas L*. seed oil at varying temperatures and shear rates.

	Viscosity (cp)			
TEMPERATURE(^{O}C)	6RPM	12RPM	30RPM	60RPM
30	151.8	82.0	42.2	25.3
40	131.9	72.7	36.3	21.1
50	127.6	67.8	31.2	18.8
60	101.2	55.0	25.4	16.0
70	98.8	51.9	22.9	14.9

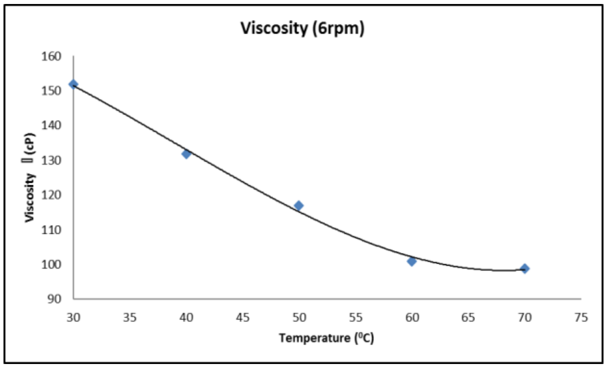

Figure 1 The shear stress as a function of temperature at 6rpm

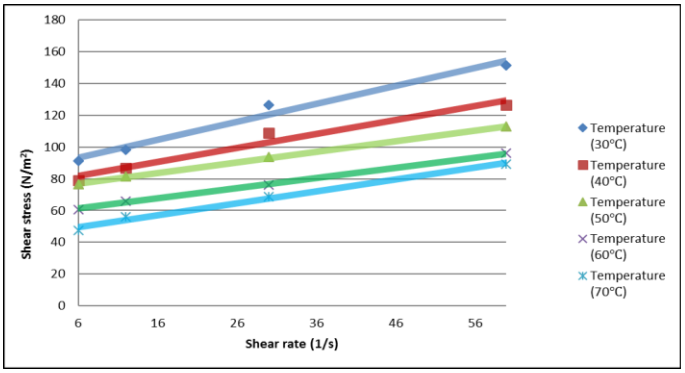

Figure 2 The shear stress of *Jatropha Curcas L.* seed oil as function of shear rate

According to the findings, a decrease in dynamic viscosity of Jatropha Curcas L. seed oil was seen as the temperature rose. Figures 1 and 2 illustrate this tendency, showing how the viscosity of Jatropha Curcas L. seed oil reduced with an increase in temperature at varied viscometer speeds. This is consistent with studies by Abdelraziq and Nierat, (2015) and Davies, (2016) as well. As the oil became lighter, the flow between the molecules became easier due to the lower inter molecular forces caused by the higher thermal movement among the oil molecules.

Figure 2 showed the dependence of shear stress of *Jatropha Curcas L.* seed oil on shear rate fitting the power law model, and the flow behavior index (n) values of the oil were between 1.10, 0.99, 0.96, 0.98, 0.97 at temperatures ranging from 30^{o}C to 70^{o}C which were very close to 1 and the consistency coefficient (K) values ranged from 0.86, 0.73, 0.57, to 0.45 for temperatures 30˚C- 70°C in multiple of 10°C. From the result, *Jatropha Curcas L.* seed oil showed a Newtonian behavior at temperatures ranging from 30^{o}C to 70^{o}C.

This study's findings regarding the shear stress show that shear stress reduces as a function of temperature and shear rate increases. The seed oil is a Newtonian fluid since all shear stress versus shear rate plots has straight lines as their boundary.

4. CONCLUSION

This research was aimed at investigating the rheological properties of *Jatropha Curcas L.* seed oil using soxhlet extraction method and the experimental investigations shows that it exhibited a Newtonian behavior at temperatures ranges from 30˚C to 70˚C and at different shear rate, shear rate and viscosity decreased with increase in temperature. The lowest viscosity was found at 70°C and 60rpm, while the maximum was found at 30°C and 6rpm. The flow behavior index and the consistency coefficient were also determined. Further research should be conducted on the rheological properties of *Jatropha Curcas L.* seed oil using different models, the viscosity should be investigated at lower temperatures to ascertain its behavior at lower temperatures and also to determine the engineering properties of *Jatropha Curcas L.* seed oil to aid in the design, processing, storage and handling equipment.

Ethical approval

Jatropha Curcas L. seed were used in the study. The ethical guidelines for plants & plant materials are followed in the study for sample collection & identification.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

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